



## In-situ TEM patterning and electrical characterisation of graphene

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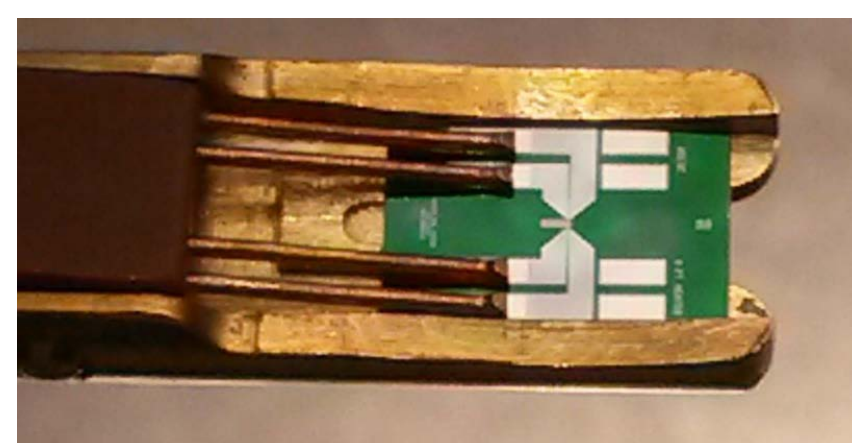


# In-situ TEM patterning and electrical characterisation of graphene

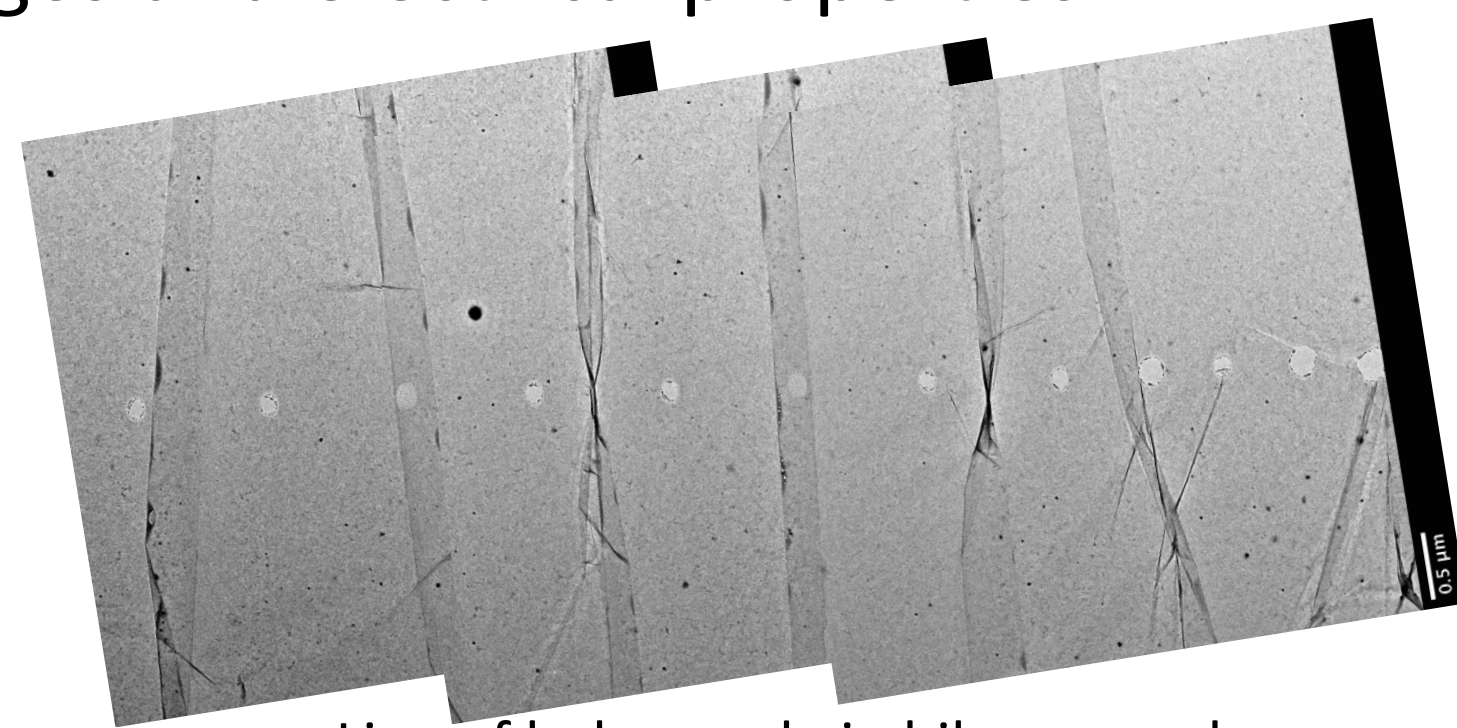
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## Introduction

- Transmission electron microscopy is an excellent characterisation tool for obtaining information about the graphene structure on an atomic scale
- It can be used to shape the graphene as well as other 2D materials (hBN, MoS<sub>2</sub>, etc) through (1) knock-on damage from the beam<sup>1,2</sup>, (2) etching via oxygen or water (in an environmental TEM), (3) nanoparticle induced etching<sup>3</sup>.
- We have fabricated silicon microchips that fit into a standard TEM holder, with electrodes to measure the electrical properties of graphene as well as for heating the samples.
- Here we present our preliminary work with graphene in-situ TEM, correlating structural changes and electrical properties



Experimental platform on TEM sample holder

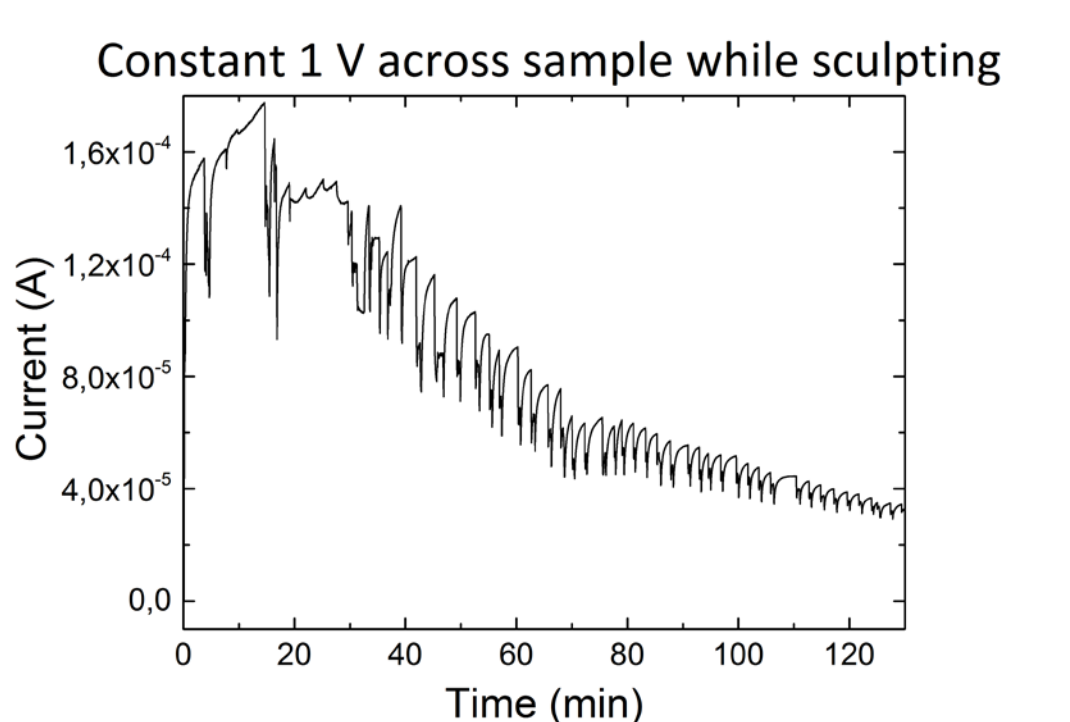
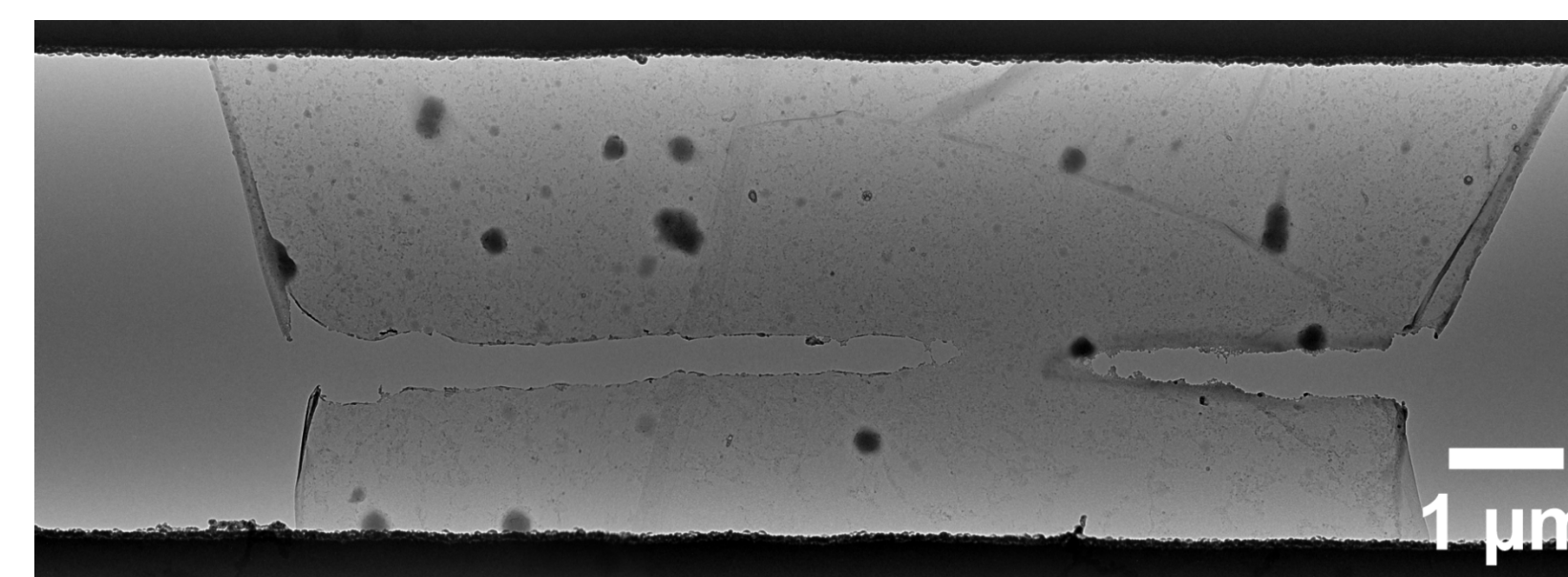


Line of holes made in bilayer graphene

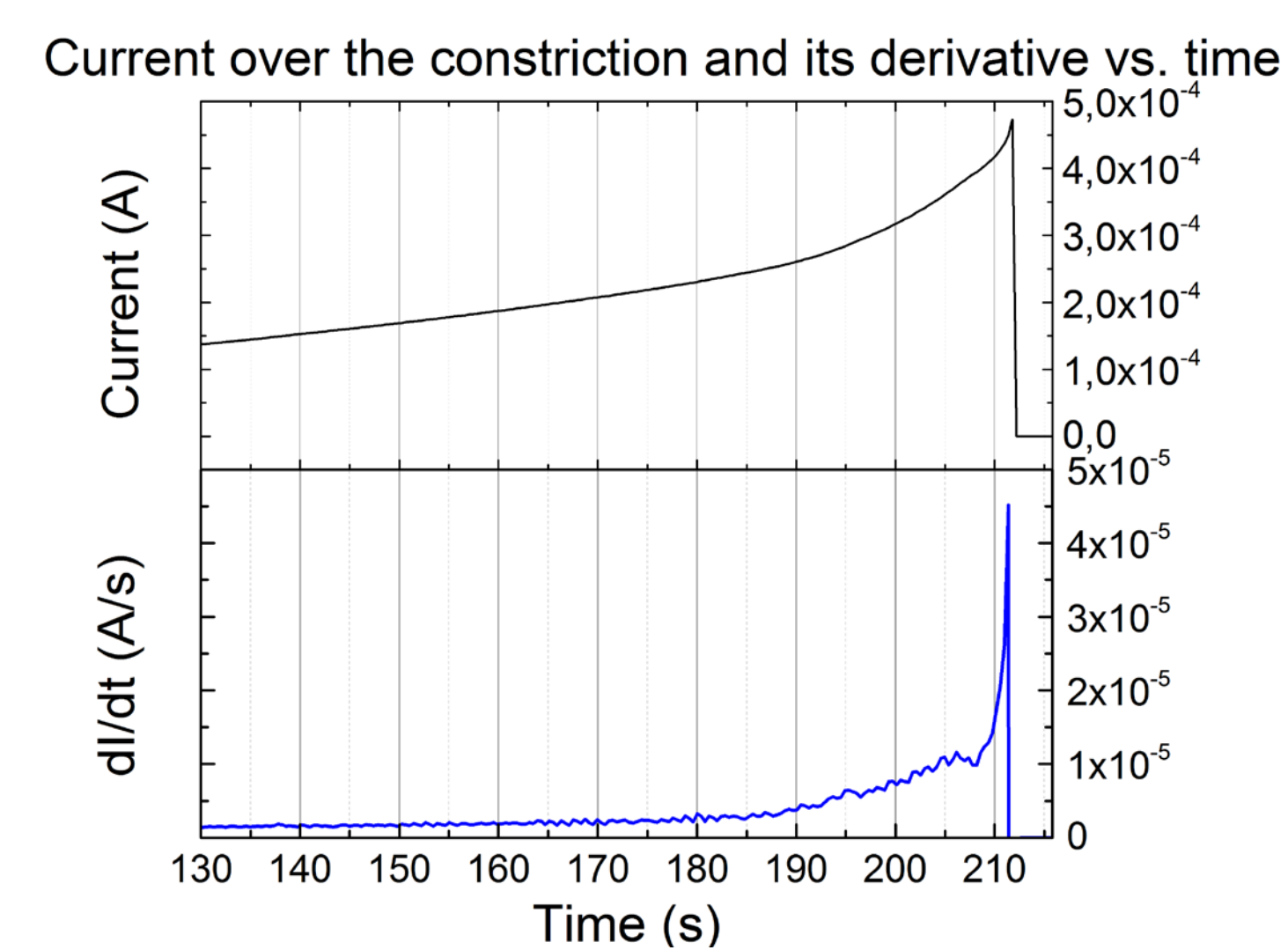
- "Correlating Atomic Structure and Transport in Suspended Graphene Nanoribbons", Z. J. Qi et al, Nano Lett. 11 (2014), 5184-5188
- "Atomic-Scale Electron-Beam Sculpting of Near-Defect-Free Graphene Nanostructures", B. Song et al, Nano Lett. 11 (2011), 2247-2250
- Discrete Dynamics of Nanoparticle Channelling in Suspended Graphene. T. J. Booth et al, Nano Lett. 11 (2011), 2689-2692

## Graphene Constrictions

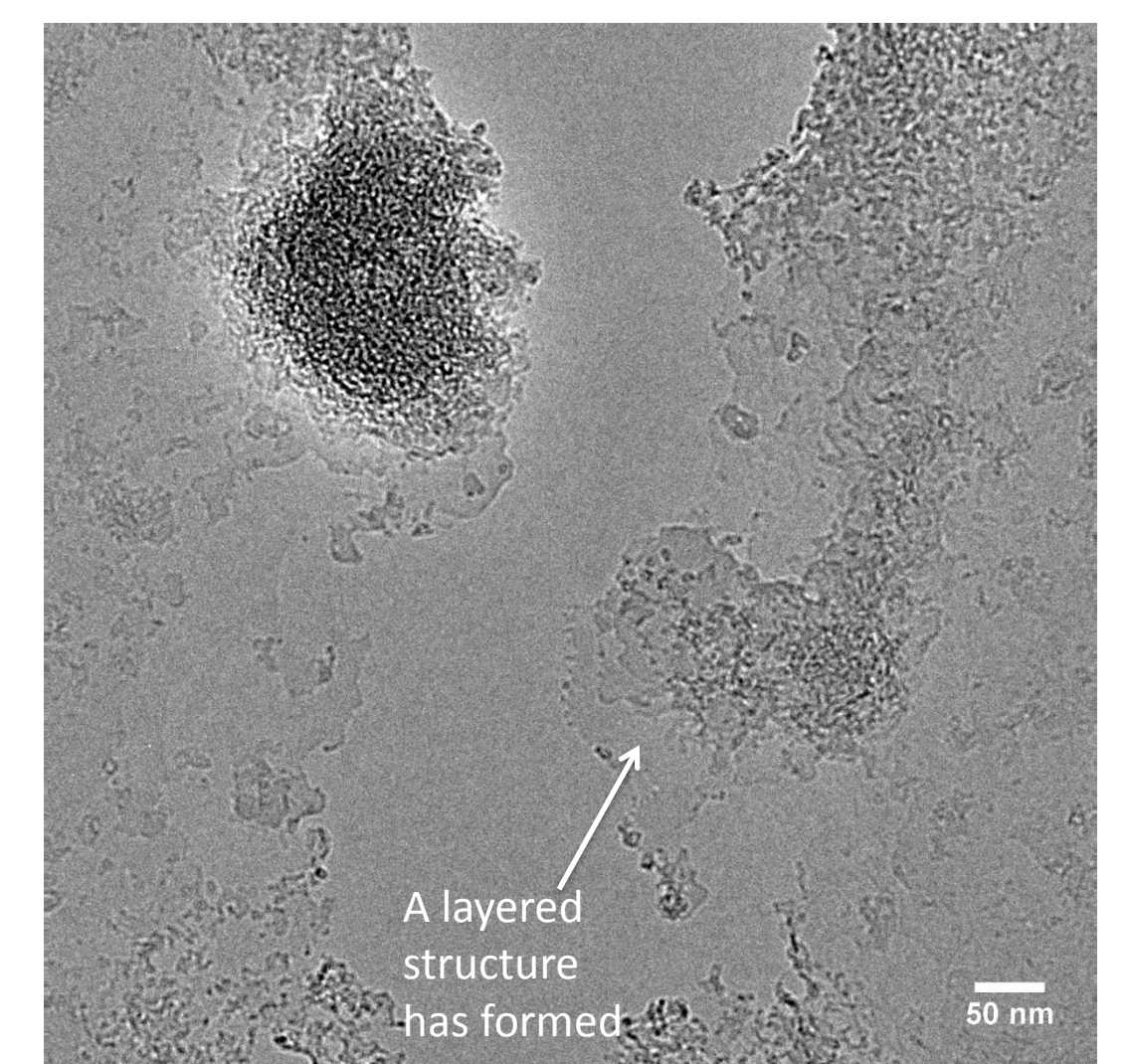
- Using knock-on damage we can structure the graphene by focusing the beam to a small area, in this case forming a constriction.



- After sculpting, the voltage across the constriction was increased until breakage



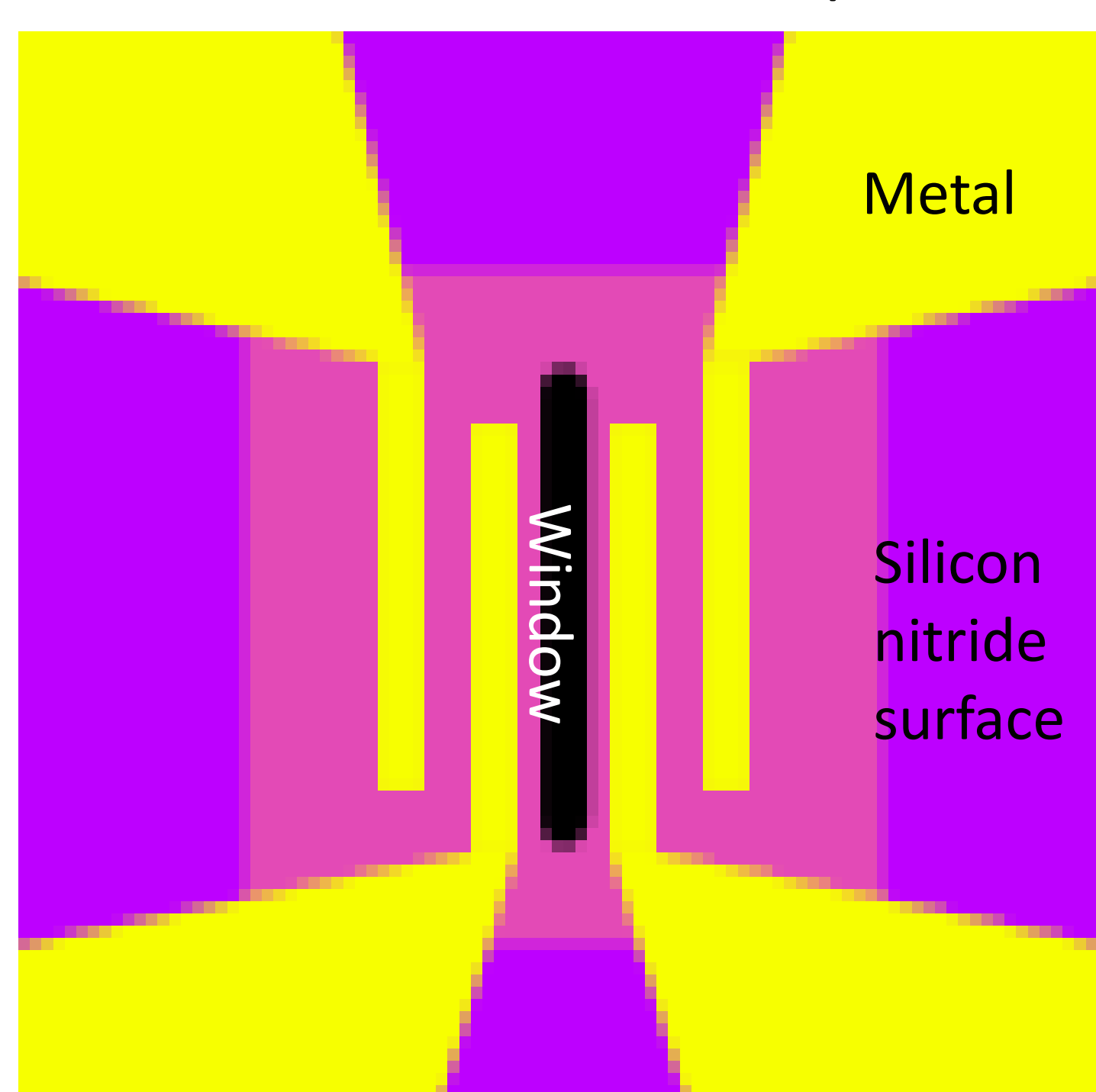
- High resolution images of the broken area shows some indications of heating



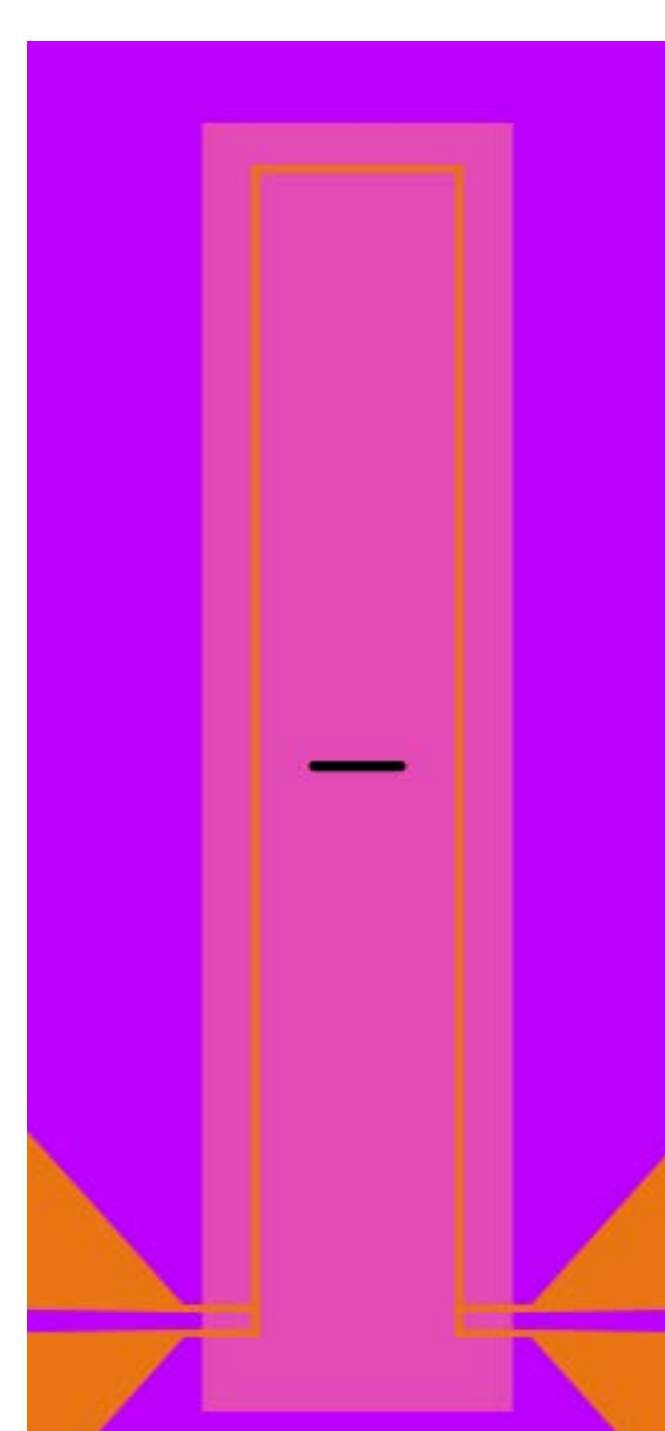
## TEM Platforms

TEM chips: Silicon nitride membrane with embedded Pt heaters and surface electrode structures for electrical measurements.

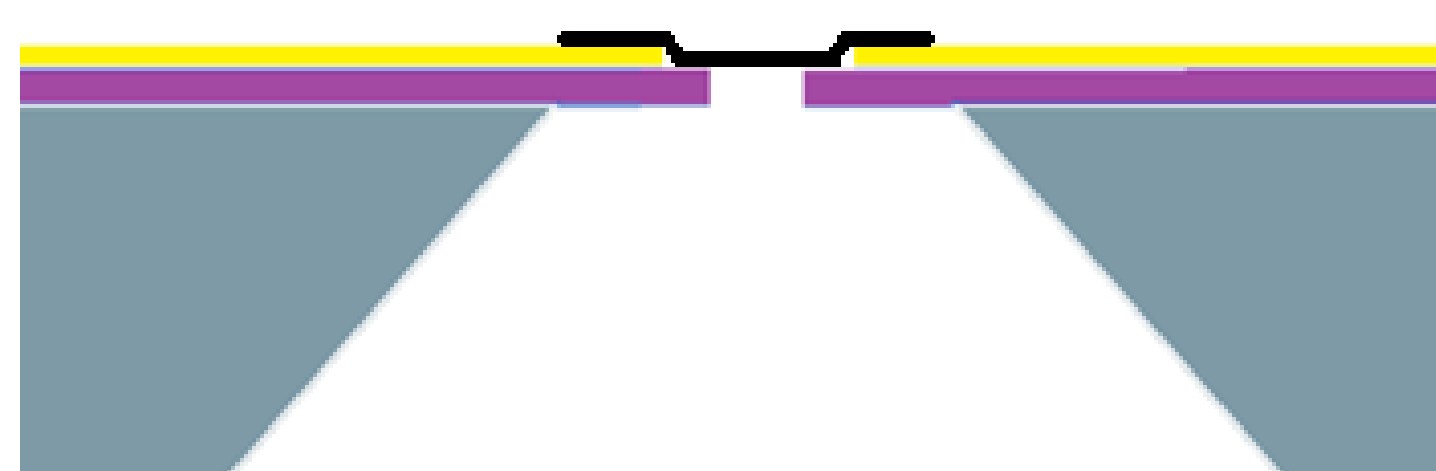
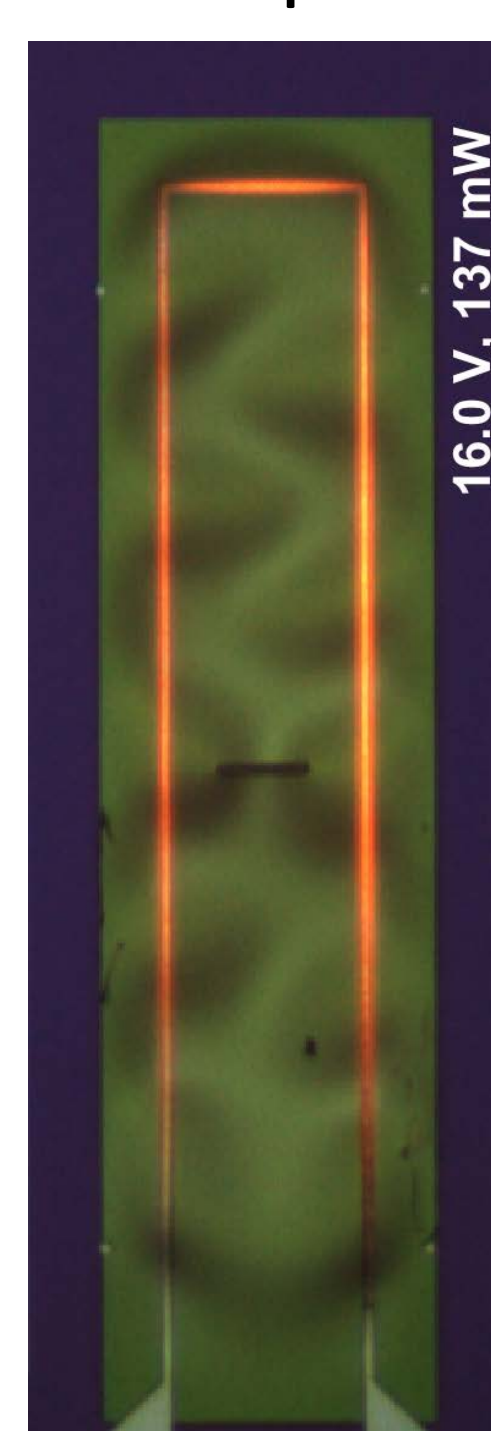
Schematic of the 4 terminal contact chip.



4-point heater structure

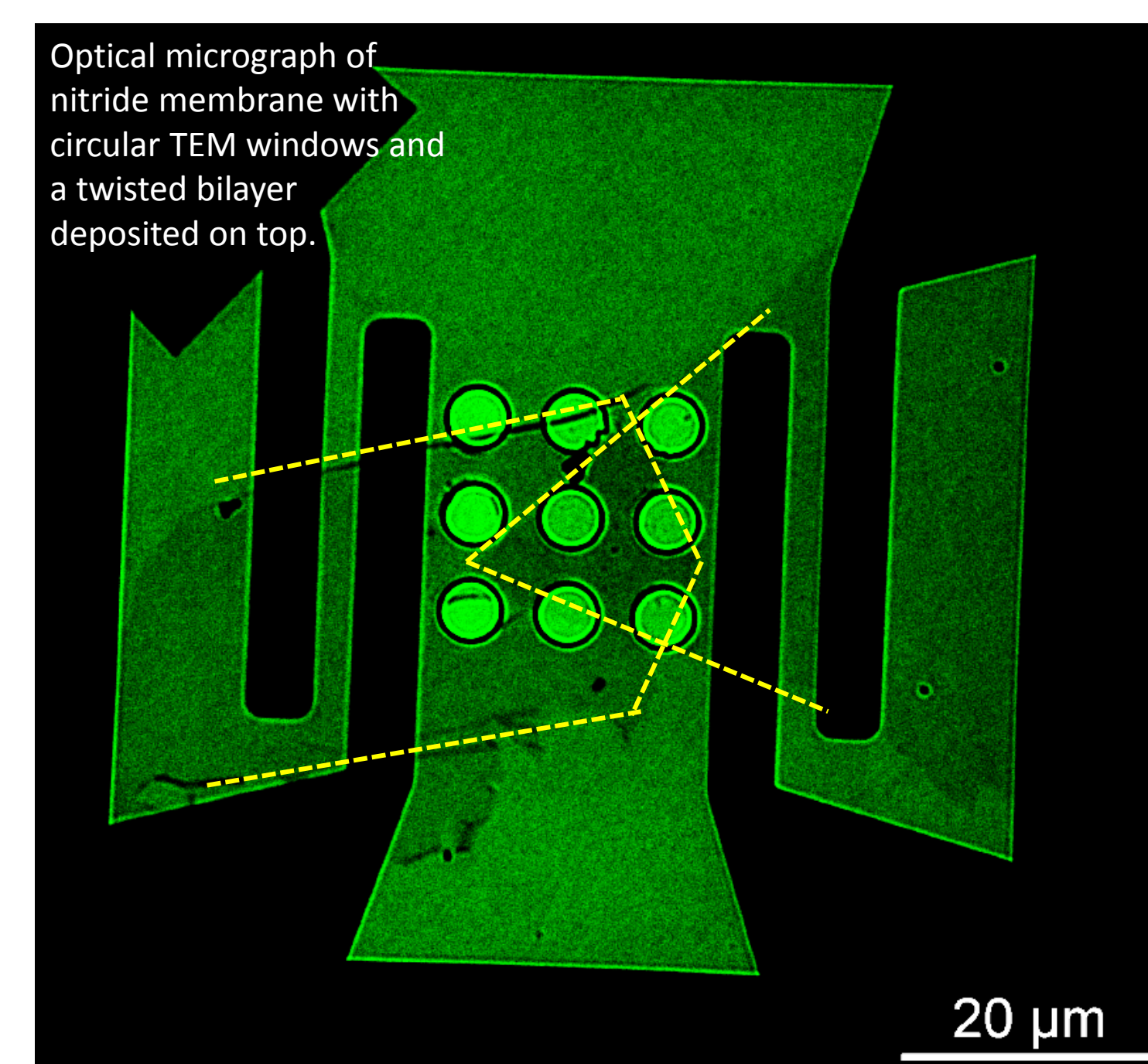


Chip glowing hot in normal atmosphere



## Twisted Bilayers

Twisted bilayers - stacked incommensurate monolayers – were made using wedging transfer. The stack is then transferred to the TEM platform.



10 twisted bilayer devices were characterised. While most samples showed linear IV characteristics, this sample showed a diode-like behavior

